National Nuclear Security Administration

LDRD
LABORATORY DIRECTED RESEARCH & DEVELOPMENT

Laboratory Directed Research and Development

At the National Nuclear Security Administration National Laboratories

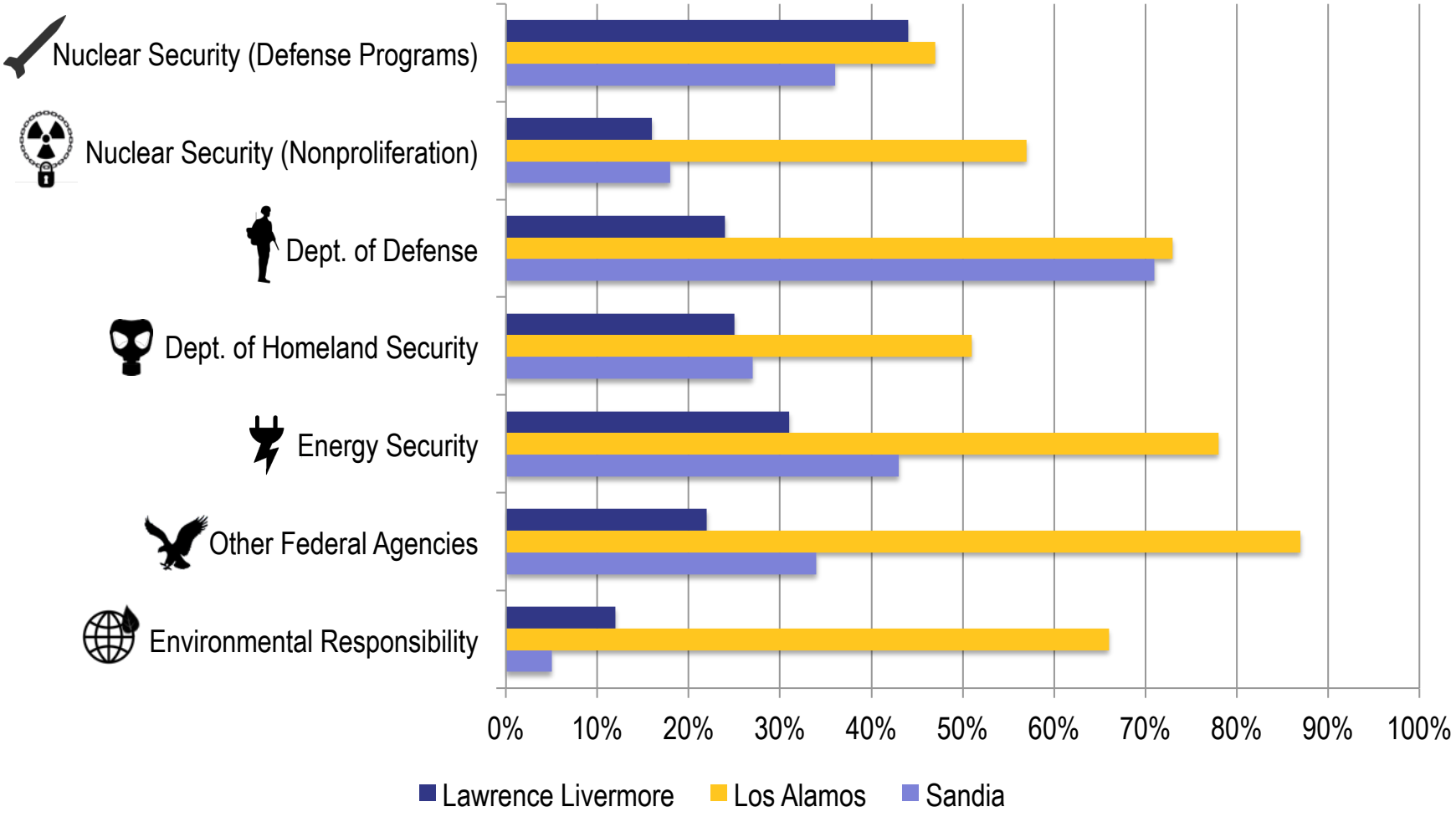
LA-UR-14-28644

Lawrence Livermore National Laboratory

Los Alamos NATIONAL LABORATORY EST.1943

Sandia National Laboratories

LDRD Supports National Security Missions



Nuclear Monitoring

Following the September 11th terrorist attack, LDRD invested in muon tomography to image nuclear threats in cargo. Today it is used as a fast, safe, cost-effective, and reliable approach to detecting nuclear materials at ports and borders.

MISSION IMPACT

- Makes it possible to detect nuclear material with *no radiation hazard*
- CRADA with Decision Sciences implemented muon tomography in a detection system currently in use at the Freeport Container Port in the Bahamas
- In use to see inside failed Fukushima nuclear reactor (unique approach)

The Multi-mode Passive Detection System (MMPDS) uses muon radiography to scan materials with no artificial radiation dose, penetrating even heavily-shielded materials to yield a 3-D image.

Detecting shielded nuclear material is faster and safer than ever with muon tomography – fewer slow, costly, and dangerous manual inspections are needed.

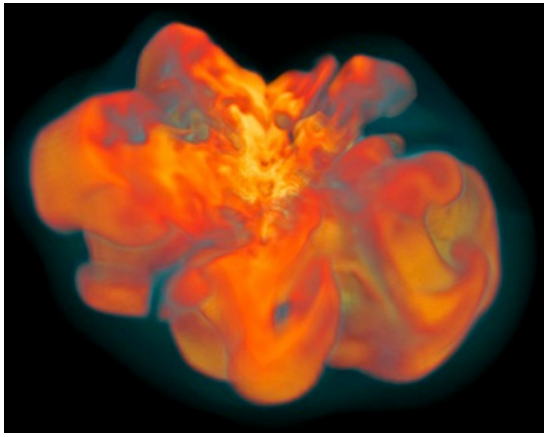
Initial LDRD project: FY2002

Testing Simulation Codes with Astrophysics

In the absence of full-scale underground tests, LDRD physicists test weapons simulation codes with supernova observations. Supernova provide environments of extreme pressure, temperature, and density – similar to what is found in a nuclear explosion.

MISSION IMPACT

- Improved code validation and verification, yielding improved prediction of stockpile performance
- Recruitment of 8 new staff into weapons physics program
- Software developed for supernovae is now used extensively within the ASC program



Using new observations of exploding stars, we can test simulation codes under extremes of pressure, temperature, and density.

Supernova are a unique way to test weapons codes in large-scale, high-energy-density environments, making it possible to ensure a safe and reliable nuclear stockpile.

Initial LDRD project: FY2007

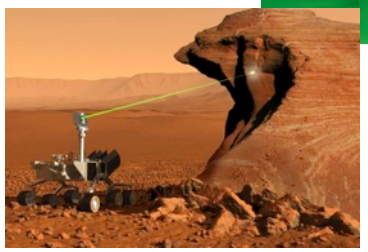
Nuclear Forensics

Laser-induced breakdown spectroscopy (LIBS) is a technique developed by LDRD that determines the composition and concentration of elements in a variety of sample types using an intense laser beam.

MISSION IMPACT

- Safe, portable, accurate, cost-effective tool for treaty verification
- Part of the IAEA "tool box" for international inspections related to nuclear materials
- A CRADA with Chevron is developing LIBS for oil refinery safety inspections (post 2012 explosion in California)
- Onboard Mars rover, Curiosity

LIBS is in backpack form for use by IAEA inspectors.



LIBS enables the Mars rover to analyze rocks from a distance.

Backpack LIBS inexpensively takes atomic emission analysis from a traditional laboratory setting into the field, making it possible to detect, verify, and study critical materials.

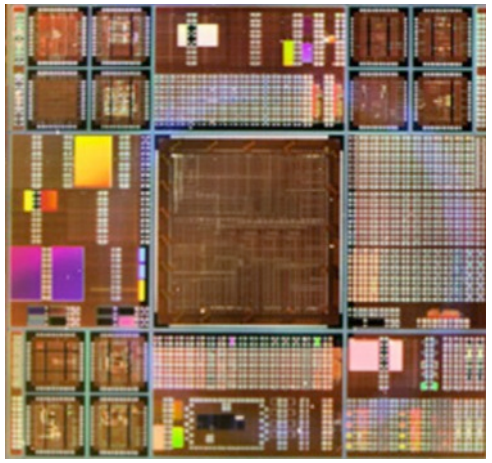
Initial LDRD project: FY2002

Radiation Hardening

LDRD funded the nation's *only* radiation-hard microelectronics capability, which is critical for NW strategic reentry performance and satellite systems.

MISSION IMPACT

- Represents the *only* radiation-hardened technology available in the U.S., forming the basis of every application-specific integrated circuit (ASIC) and rad-hard transistor produced for nuclear stockpile and non-proliferation missions
- Strategic advantage gained due to integrated circuits immune to ionizing radiation
- Understanding the physics of radiation and ion beam damage on semiconductor materials and circuits



Radiation-hardened ASIC

25,000 rad-hard ASICS for 10 major NW components will be produced from FY16-FY25.

Initial LDRD project: FY1997

Miniaturized Radar Systems

Miniaturized electronics with advanced software allow for novel synthetic aperture radar (SAR) systems to be applied across mission areas.

MISSION IMPACT

- Lightweight SAR strengthened RF competencies leveraged in NW Life Extension Programs
- Numerous tactical warfare and civilian applications (e.g., intelligence, force protection in theater, damage assessment, search and rescue, nonproliferation/treaty verification)

Copperhead miniSAR mounted on a Tiger Shark UAV

"[This sensor] was very useful in Iraq. We shifted them to Afghanistan and they are our best detection platform for this one type of IED."

Lt. Gen. Michael Barbero, Defense Department, Joint IED Defeat Organization Director

***Hundreds* of lives have been saved since "Copperhead" miniSAR was mounted on UAV's, providing IED detection 24/7.**

Initial LDRD project: FY2001

Radioactive Seawater Cleaned with CSTs

LDRD funded synthetic zeolites, known as crystalline silico-titanates (CSTs), were designed to absorb radioactive cesium.

MISSION IMPACT

- Invented at Sandia in the 1990's as part of an LDRD project, quick action by Sandia researchers in 2011 put CSTs to work cleaning Fukushima Daiichi's water
- Sandia worked with UOP, a Honeywell Company, to commercialize the technology in both powder and pelletized forms.
- Tens of millions of gallons of radioactive liquid waste from mining, nuclear power generation, and the nation's nuclear stockpile require treatment that CSTs could provide

Aerial view of Fukushima Daiichi nuclear plant after the earthquake

85 million gallons of radioactive cesium contaminated waster at Fukushima has been cleaned with CSTs developed in an LDRD project.

Initial LDRD project: FY1995

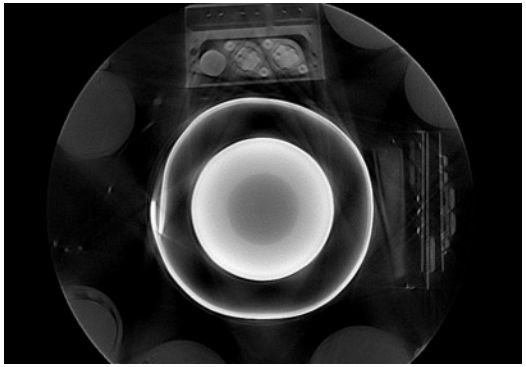
Pit Inspection System at Pantex

Three-dimensional X-ray Imaging for Stockpile Surveillance

LDRD investment in novel x-ray imaging methods enabled a cost-effective pit inspection system. Investment in novel materials are also enabling a next-generation inspection system with much higher throughput.

MISSION IMPACT

- Delivered the world's highest-resolution, high-energy x-ray tomography system to Pantex; transformed and modernized surveillance in support of the annual assessment
- 3D CT allows us to measure and resolve features that would have gone undetected—thereby improving confidence
- Cost savings: typical destructive tests cost >$1M/pit; nondestructive CT cost $200k/pit and is critical for preserving valuable assets
- System is oversubscribed; a second unit is being implemented at Pantex



X-ray image of test object.

This technology enables certification of pit reuse for LEPs and saves the nation billions of dollars by reducing the short-term need for a costly, large-scale manufacturing capability.

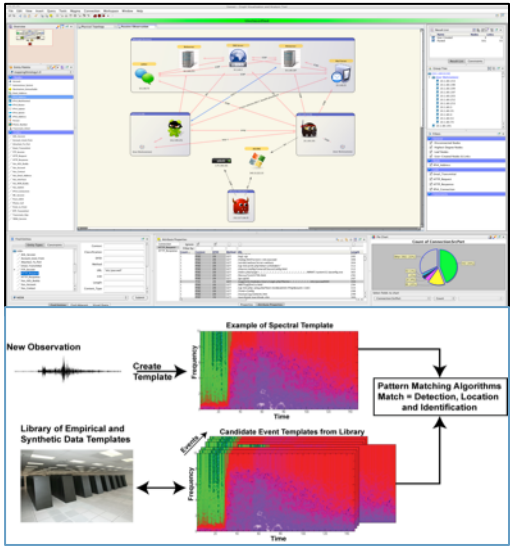
Initial LDRD project: FY1989

Investment in Sensors and Data Science

LDRD investments in network mapping, cyber activity analysis, and large-scale data analytics provide capabilities that have become operational and are helping to protect our troops.

MISSION IMPACT

- R&D in mapping networks and information flows reduces mapping time from weeks to hours – in use on Army and other government networks – DOD base mapping times decreased from >1 week to <6 hours
- Record-breaking network simulation speed of >500 billion events/second predicts cyber attack impact and best response
- In support of global nuclear explosion monitoring, increased seismic event analysis rate by 100x while significantly reducing detection threshold



New analytic algorithms and tools are easing the burden on cyber and seismic analysts

New analytic tools enabled by ever-growing data streams and high-performance computing are greatly increasing the efficiency of human analysts in high-priority national security applications.

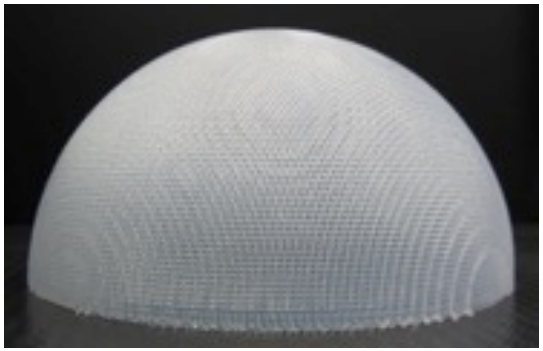
Initial LDRD project: FY1999

Additive Manufacturing

LDRD is developing novel additive manufacturing (AM) methods to create architected materials and computational models of metal-based AM processes.

MISSION IMPACT

- New manufacturing processes for cost-effective modernization of a safe, secure, and effective stockpile
- Processes to produce qualified tooling at production agencies could reduce related schedule delays by 50%
- Technologies are being transferred to the Kansas City Plant and Y12
- Cushions developed using the AM processes could enable 10X reduction in facility footprint, 85% decrease in manufacturing cost, and improve homogeneity by 70%
- Implementation could occur in B61 and W88 this decade

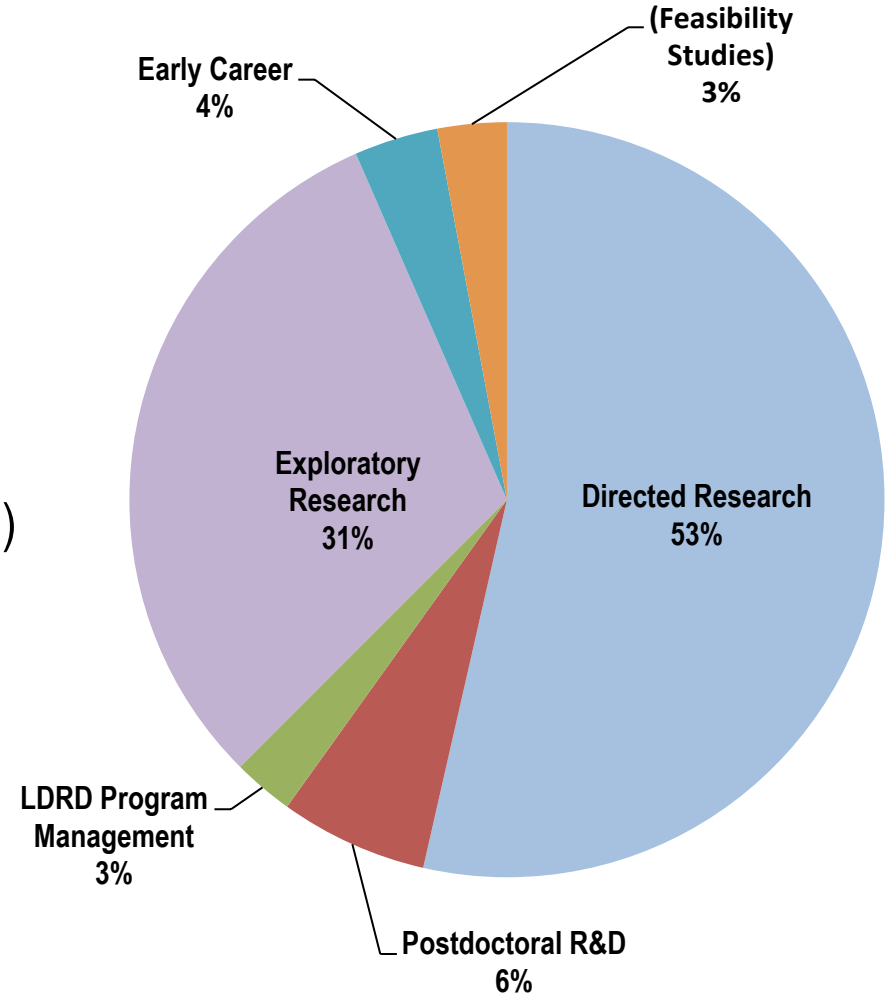


First compliant 3D cushion component created by LDRD-developed processes

AM will enable a more responsive NSE, reduce production costs, accelerate the design and certification cycle, and inform our understanding of risk of technological surprise.

LDRD Develops Ideas and People at Los Alamos for Mission Readiness

- **Directed Research (DR) $78M**
  Projects with a multidisciplinary approach to hard problems (~4 FTE)
- **Exploratory Research (ER) $45 M**
  Basic and applied research projects directly from the staff (~1 FTE)
- **Early Career Research (ECR) $5.2M**
  Developing emerging leadership (~.5 FTE)
- **Postdoctoral R&D (PRD) $9M**
  Innovative projects fund highly sought-after postdoc fellows
- **Feasibility Studies ($5.2M)**
  Address emerging S&T needs



Los Alamos NATIONAL LABORATORY

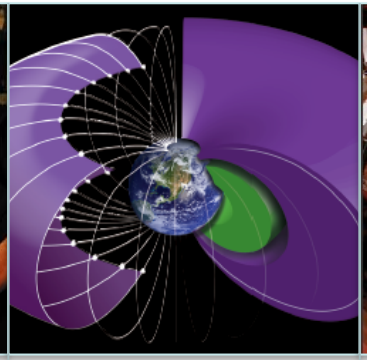
Los Alamos LDRD Focus Areas

Information Science and Technology

Computational Co-Design and Data Science at Scale

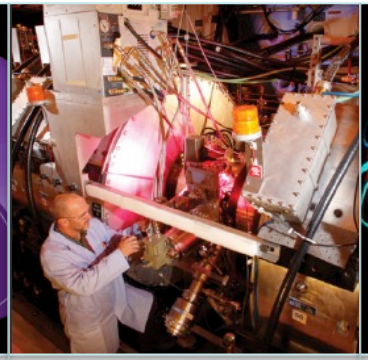
Materials for the Future

Controlled Functionality via Discovery Science



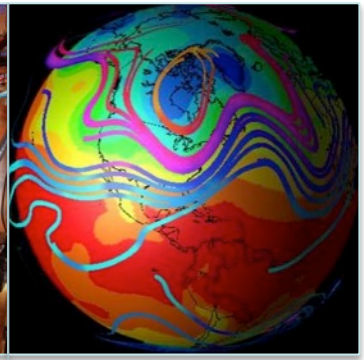
Science of Signatures

Discover Signatures, Revolutionize Measurement, and Forward Deployment



Nuclear and Particle Futures

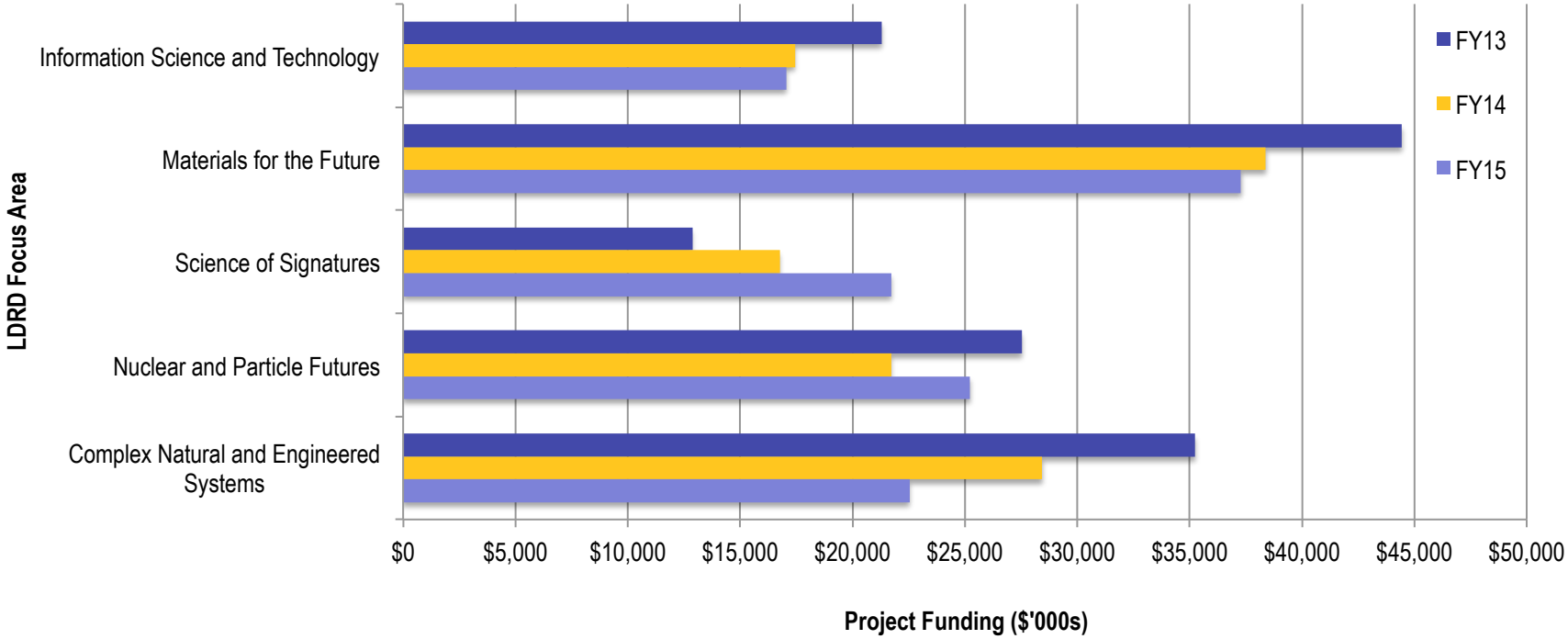
Scientific Vitality in All Things Nuclear



Complex Systems

Understanding and Controlling Interfaces and Interactions

Los Alamos Investments in LDRD Focus Areas



Los Alamos NATIONAL LABORATORY

LDRD Helps Sandia Maintain Strong Laboratory Capabilities

LDRD Program Anchored by Research Foundations - 30%

Anticipate future research needs and capabilities for NW and our other national security missions

- Engineering Sciences
- Materials Sciences
- Radiation Effects and High-energy Density Sciences
- Computer and Information Sciences
- Biosciences
- Geosciences
- Nano-devices and micro-systems

LDRD Program tackles bold, high-risk topical research challenges - 15%

- Grand Challenges – enormous potential for impact on national security

LDRD Program builds research talent through corporate investments - 22%

- Pipeline programs, early career R&D, partnerships

LDRD Program builds capability for nearer-term mission needs– 30%

- Mission foundation research and development

Laboratory foundation sustained by people, research and capability

Sandia National Laboratories

Sandia LDRD Focus Areas

Nuclear Weapons

Science-based tools for revolutionary and agile development and design

Pulsed-power research

Science of component and material aging, reliability and failure

Nuclear Nonproliferation

Technologies and systems to assess, analyze, detect and respond to nonproliferation threats

Cyberspace

Modeling and analysis of cyber operations and attack behaviors

Technologies for increasing trust and network-resilience

Science and technology of quantum information systems

Synergistic and Leveraged Defense Applications

Develop differentiating ballistic and hypersonic flight technologies

Develop advanced detection and tracking technologies

Secure and Sustainable Energy Future

Technologies and systems for energy storage, secure grids, renewable energy and U.S. energy security research

Reducing Chemical and Biological Dangers

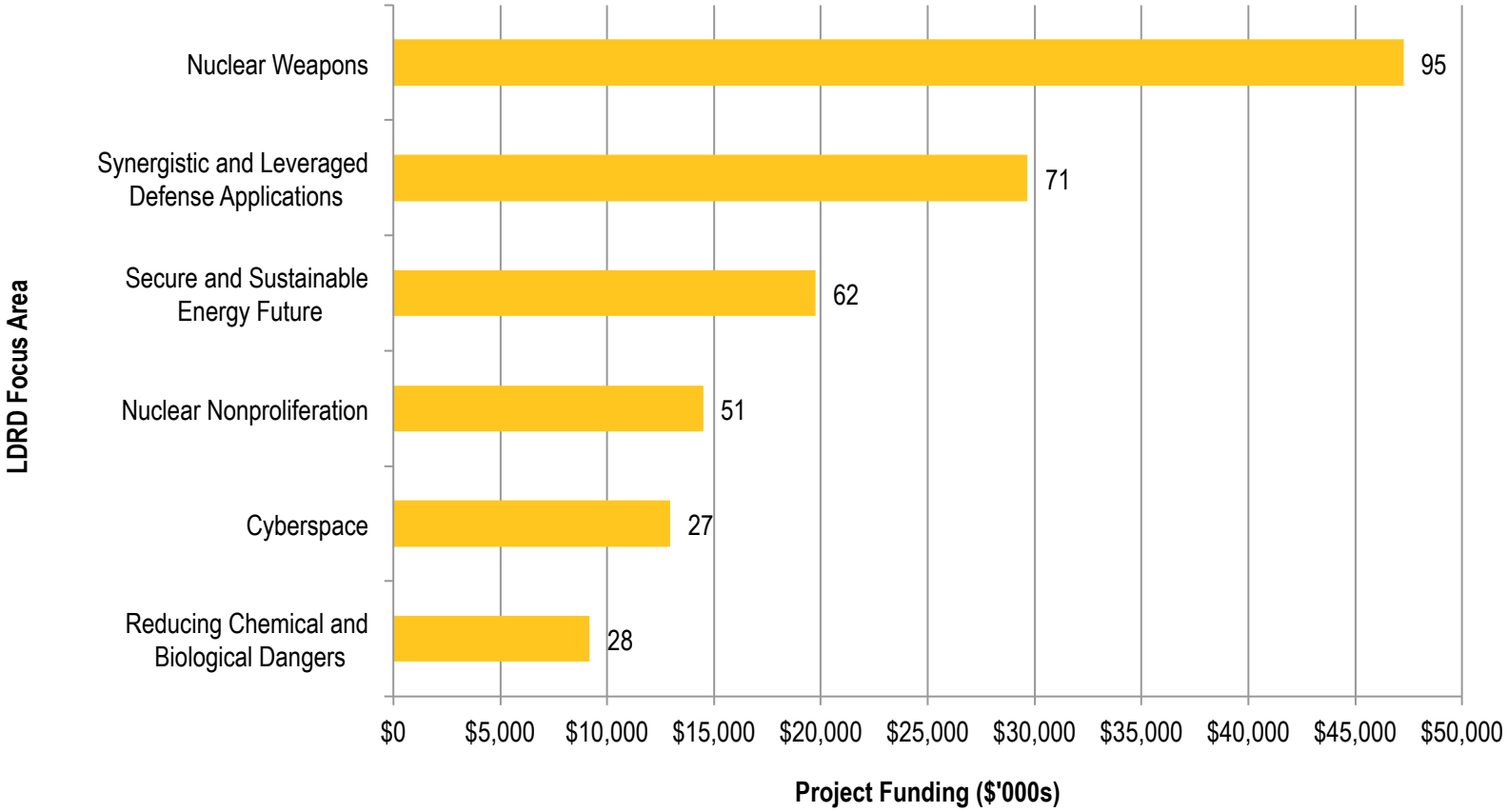
Develop cost-effective detection methods for chem-bio defense

Technologies to counter natural and engineered bio-threats

Note that these example-investments capture most, but not all of the S&T strategy

Sandia National Laboratories

FY15 Sandia Investments in LDRD Focus Areas



Sandia National Laboratories

Lawrence Livermore LDRD Investment Categories

Strategic Initiatives (SI)

- Involve large multidisciplinary cross-organizational teams
- Funded for up to three years at $1.5M to $3M per year

Exploratory Research (ER)

- Investment in the Laboratories core competency areas (typically <$1.5M)

Laboratory-wide Competition (LW)

- Small projects serve as a critical incubator for proposals from Early Career personnel (<$300K)

Feasibility Study (FS)/Project Definition (PD)

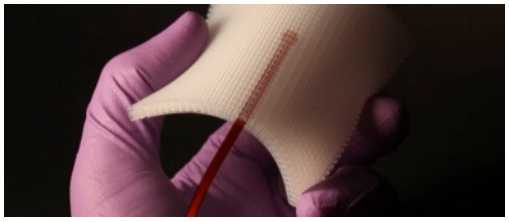
- Less than $125K and 12 month in duration

Lawrence Livermore LDRD Focus Areas

Nuclear Security → Other National Security

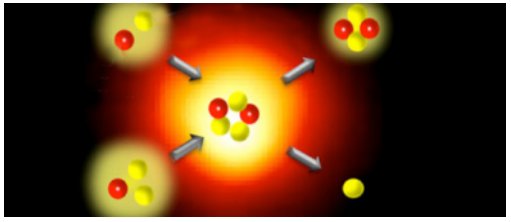
High-Energy-Density Science

Advanced Materials and Manufacturing



Chemical and Biological Security

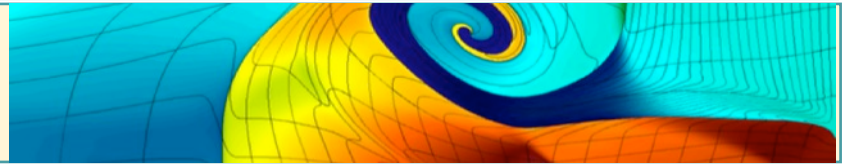
Nuclear and Isotopic Science & Technology



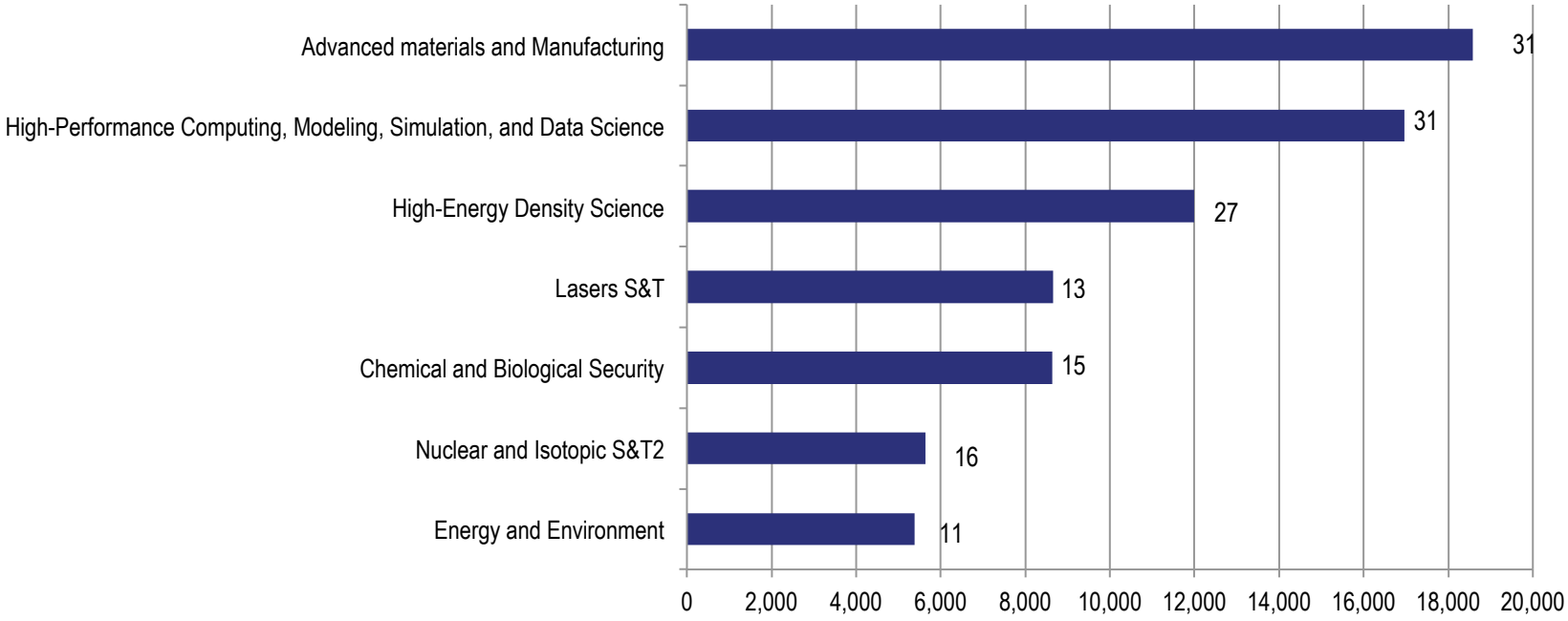
Lasers Science and Technology

Energy and Environment

High-performance Computing, Simulation, and Data Science



FY15 Lawrence Livermore Investments in LDRD Focus Areas



LDRD Recruits Top Talent to the NNSA Laboratories

LDRD attracts top-notch postdocs to the NNSA Laboratories. Most convert to full time staff, foregoing the prestige and visibility of academic careers, and choose to devote their talents to advancing national security missions.

Postdoc Support (FY13)

	Los Alamos	Sandia	Lawrence Livermore
Lab Total	532	216	243
# Supported by LDRD	317	97	123
% Supported by LDRD	60%	45%	51%

Postdoc Conversions (FY13)

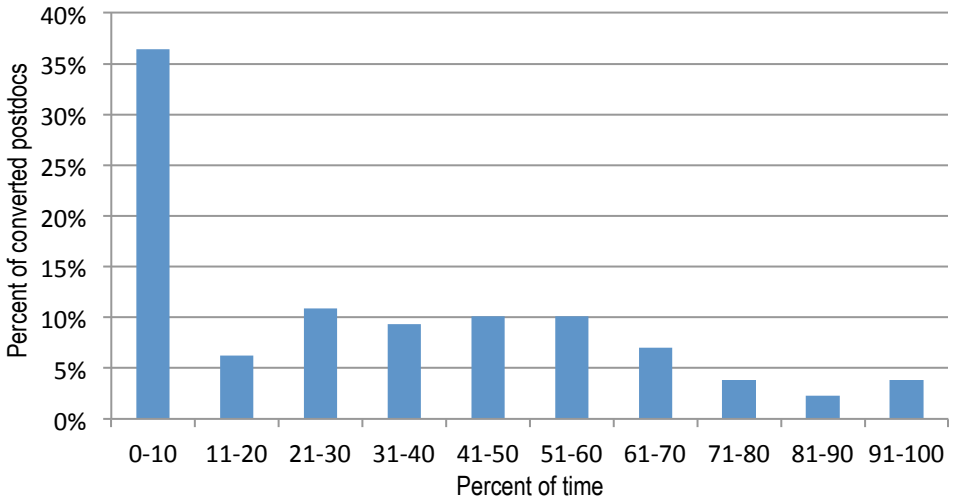
	Los Alamos	Sandia	Lawrence Livermore
Lab Total	57	31	47
# Supported by LDRD	34	18	37
% Supported by LDRD	59%	58%	79%

At Los Alamos, 82% of non-management PhD hires FY10-13 are former postdocs.

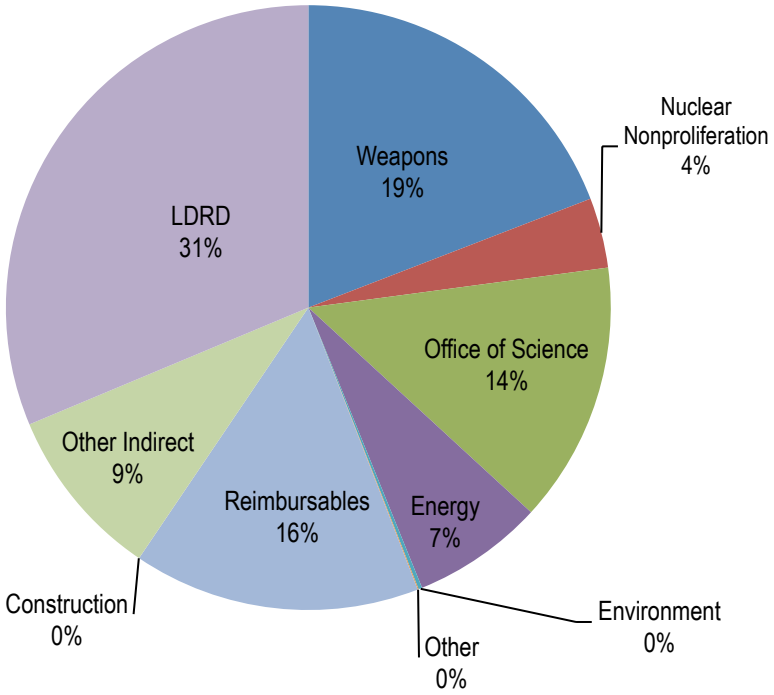
Recruit, Retain, Transition

At Los Alamos, about 70% of LDRD-supported postdoc conversions spend most of their time on *non-LDRD* programs and contribute to a wide range of missions. A small fraction participate in LDRD projects building capabilities for future programs.

LDRD-supported Postdoc Conversions
(FY07-FY13)
% time currently charged to LDRD



LDRD-supported Postdoc Conversions (FY07-FY13)
Current Contributions to Programs



FY07-FY13: 152 LDRD-supported postdoc conversions 152
FY14: 129 still active at the Laboratory,

Los Alamos NATIONAL LABORATORY

Early Career Researchers Support the NW Mission

LDRD helps Sandia maintain a strong human capability base.

- 200+ postdoc hires have led to early-career LDRD projects since FY10
- In FY12, 300+ students (high school, undergraduate, graduate) contributed to LDRD projects
- In FY13, nearly $7M of LDRD funding for strategic university partnerships

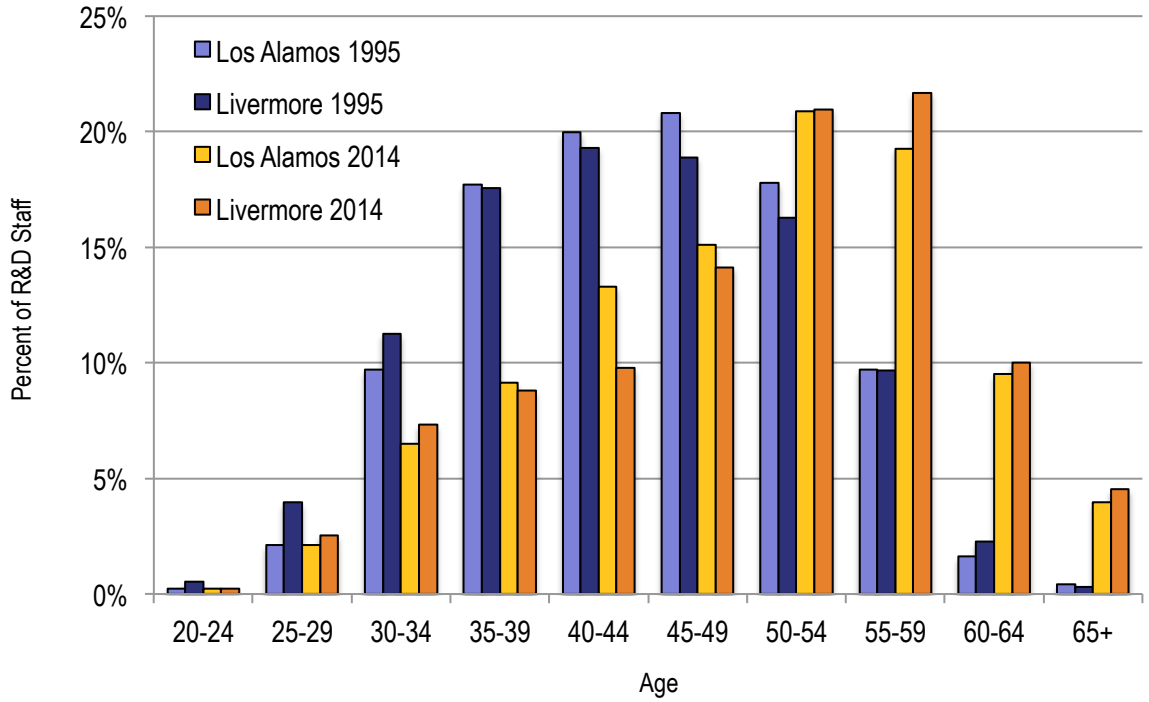
By FY2013, over 50% of Early Career LDRD researchers were already working on nuclear weapon programs; these new researchers further nurture Sandia's science and engineering capabilities base essential to the stockpile.

LDRD sets the foundation for integrated experiments and attracts next-generation researchers to Los Alamos. For example, LDRD recruited all the early-career contributors to the Gemini project.

- Early-career researchers have expertise needed for modern stewardship tools
  - Physics modeling, diagnostics, fabrication, and engineering

Human Capability: Our Most Critical Asset is at Risk

A generational turnover is upon us: the workforce at the NNSA laboratories is aging and new generation of talented scientists and engineers must be recruited, trained, and retained.



Competition for talent from industry and academia is fierce.

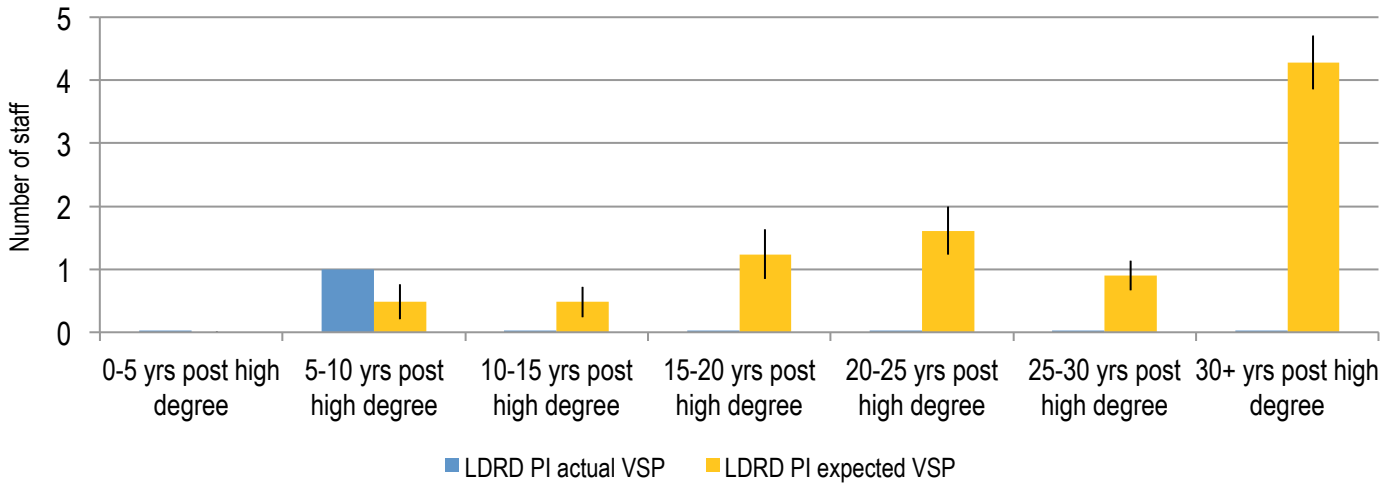
LDRD is our primary tool to attract the best and brightest.

25% of the Sandia R&D workforce is eligible for retirement.

LDRD Has a Strong Effect on Retention

Analyses of a recent voluntary separation plans at the NNSA laboratories show LDRD improved the retention of key staff, proving that LDRD is essential for retaining critical R&D talent.

Los Alamos VSP
LDRD researchers left at a rate 1/10 the general population



2013 Assessment of Sandia Early Career Program: Survey Results

- 72% of Early Career PIs cite LDRD funding as a significant contributing factor for continuing their career at Sandia
- 40% of Young PIs cite LDRD as an important reason why they came to Sandia

LDRD Contributes Significantly to the Intellectual Vitality of the NNSA National Laboratories

	Peer Reviewed Publications (FY13)	Patents (FY13)	R&D 100 Awards (FY08-FY13)
NNSA Lab total	4308	267	78
# LDRD supported	1112	129	49
% LDRD supported	25%	48%	62%

Other Awards and Recognitions

Office of Science Early Career Awards
Presidential Early Career Awards
E.O. Lawrence Awards
Edward Teller Awards

Asian American Engineer of the Year
Federal Laboratory Consortium
Fellows of Professional Societies
TechConnect Innovation Award

Independent Reviews of LDRD

NATIONAL ACADEMY OF SCIENCES

"The study committee recommends that Congress and NNSA maintain strong support of the LDRD program as it is an essential component of enabling the long-term viability of the Laboratories." - The National Academy of Science Review of Science and Engineering at the NNSA labs, 2013

"The novel and innovative approaches supported by LDRD are essential to the nuclear weapons mission." - The National Academy of Science Review of Science and Engineering at the NNSA labs, 2012

"LDRD is the most highly leveraged investment we have."
- Norm Augustine, 2012 LDRD Symposium

"The LDRD program is critical to keeping NNSA and its national laboratories and sites in the frontlines of science and technology and to recruiting and retaining the next generation of nuclear security professionals
- Tom D'Agostino, former NNSA Administrator

NNSA National Nuclear Security Administration

Independent Reviews of LDRD
(Los Alamos)

2011 Review of Effectiveness of Los Alamos LDRD Program
Chair: Raymond Jeanloz, UC Berkeley, National Academy of Sciences

Noteworthy Practices:

- The LDRD Program at LANL is critical to maintaining cutting-edge science and engineering capability and a world-class workforce
- Uses world-class methods to assess the quality of proposals, modeled after the best practices of peer-reviewed applied at the NSF, NIH, and NASA
- The use of external reviews in the selection and performance reviews provides a calibration against similar work in the broader research community
- Numerous examples of projects funded by LDRD … have resulted in significant new capabilities used by LANL and the broader national security and scientific communities

Recommendations:

- Metrics to assess scientific risk across the portfolio
- Regular review of strategy
- Mechanisms for measuring project impacts

2013 Review of Early Career S&T Pipeline
Lead: France Cordova, Purdue University

Noteworthy Practice:

"The Lab has wisely developed its own Early Career [program] using LDRD funding. This new program should serve to keep and inspire the best young scientists and engineers as they are in their formative early years as staff members at the Lab.

Recommendation:

LANL must increase student and postdoc recruitment efforts to broaden and diversify candidate pools.

Independent Reviews of LDRD
(Sandia National Laboratories)

Feedback on the quality of the science:

Nanodevices & Microsystems – "remarkable, world-class"
Radiation Effects & HED Science – "mostly classified work, high quality publications"
Engineering Sciences – "highest quality, cutting-edge, innovative, creative"
Bioscience – "impressed, leading edge, extremely high quality"
Materials Science & Technology – "highest quality seen to date, impressive"
Computer & Information Science – "high-caliber, excellent, among the very best"
NW and DSA – "outstanding, leading-edge, exceptional, impressive, innovative, creative"
Grand Challenges – "uniformly rated as high quality by each External Advisory Board"

Recommendations:

*Inc*rease emphasis on Why Sandia?
Balance Portfolio
Increase Documentation and Communication of Impact

Sandia Research Advisory Board Report
Spring Meeting, March 27-29, 2012

Independent Reviews of LDRD
(Lawrence Livermore)

- **Reviewing LDRD projects is an essential element in all of our External Review Committees' meetings**
- **An External Review Panel was convened to review LDRD in September 2011, with membership from across academia, national labs and industry**
  - LLNL's LDRD program has been vitally effective in maintaining the Lab's innovation stream
  - LDRD projects have numerous impacts beyond the scientific research
    - …sustaining a talent pipeline in certain areas, such as radiochemistry
    - Establish the prestige of the LDRD program and its role in developing the Lab's future leaders
    - Track and document the success of LDRD projects—Require acknowledgment of LDRD support in publications
- **From the 2012 S&T Advisory Panel**
  - The LDRD investments [in Cyber, Space and Intelligence] have been very successful and highly leveraged. The overall return on investment regarding intellectual capital, human capital, and new business is impressive.
  - Internal investments [in the weapons area] have paid off well. The Climate UQ LDRD Strategic Initiative (SI) has advanced UQ science that is relevant to stockpile stewardship. The plasma–simulation SI has produced new insights and capabilities that are relevant to high-fidelity modeling of plasmas and that may improve our understanding of boost. The LDRD projects have helped to attract talent into the weapons program.

LDRD Program Management

The LDRD program follows a strategic guidance derived from the missions of the U.S. Department of Energy, the National Nuclear Security Administration, and the Laboratory.

Project selection follows best practices established by the National Science Foundation and National Institutes of Health

LDRD is a fair and open competition for ideas across the breadth of the Laboratory

Independent peer-review of new and ongoing projects ensures top quality

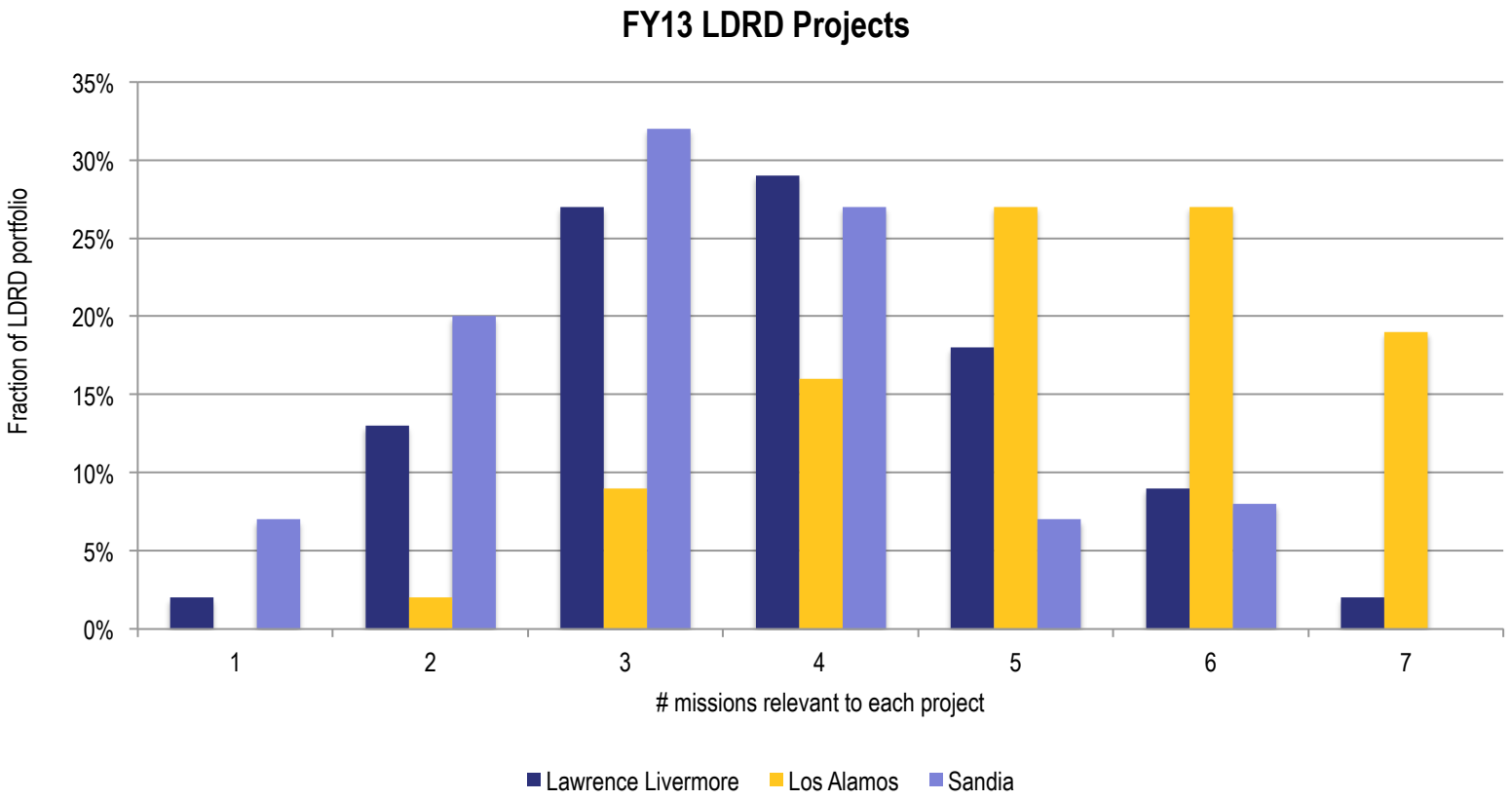
Projects are evaluated annually for progress, mission relevance, and alignment with Laboratory S&T strategies

NNSA OVERSIGHT AND ANNUAL PROGRAM CONCURRENCE

A rigorous down selection of 10-15% of proposals submitted ensures quality LDRD projects are funded.

Multi-mission Impact

Because LDRD invests early in the R&D cycle, the majority of projects are relevant to multiple missions.



Mission areas: Nuclear Security, Energy Security, Scientific Discovery and Innovation, Environmental Responsibility, Dept. Homeland Security, Dept. Defense, Other Federal Agencies